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Growth assessment of area, production and productivity of root and tuber crops and agricultural growth in Nigeria: implications for food security

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ABSTRACT

This study assessed the growth rates and doubling time of the area, production and productivity of root and tuber crops and agricultural growth in Nigeria and their implication on food security. Annual time series data collected from the archives of Food and Agriculture Organization (FAO) and World Bank database spanning from 1981 to 2020 were used in the study. The data were analyzed using descriptive statistics and growth. The result showed that the instantaneous growth rates of area, production and productivity of root and tuber and agricultural growth was 8.31%, 11.17%, 2.89% and 2.80% respectively. The result further showed that the compound growth rates of area, production and productivity of root and tuber and agricultural growth was 8.67%, 11.83%, 2.92% and 2.84% respectively. The study also revealed that the doubling time (number of years it will take to double the rate of growth) of area, production and productivity of root and tuber and agricultural growth was 7.96 years, 5.84 years, 23.63 years and 24.29 years respectively. The study concludes that the area, production and productivity of root and tuber and agricultural growth rates in Nigeria has not been at an exponential rate as evidenced by the decelerated growth pattern of the variables over time in Nigeria. This trend and pattern of growth is not healthy in addressing food security in Nigeria as the nation continues to battle with the grappling effects of food insecurity. The study therefore recommended that Government should develop new policies, institutions and financing structures to increase root and tuber crops production and productivity and consequently drive sector growth as the sub-sector is crucial in reducing food insecurity in Nigeria.

Keywords: Growth, Root & Tubers, Agriculture, Productivity and doubling time.

DISCOVERY SCIENTIFIC SOCIETY

1. INTRODUCTION

Agriculture as a major contributor to Nigeria's economy, provides primary means of employment for Nigerians and accounts for about one quarter of total Gross

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Domestic Product (National Bureau of Statistics, 2020; Aboyeji & Aguda, 2021), with more than 60% of the working adult populations employed in the agricultural sector directly or indirectly (NBS, 2019). The agricultural sector comprises crop production, livestock production, fishery and forestry. Crop production is the dominant activity accounting for 87.6%, relative to livestock (8.1%), fishery (3.2%) and forestry (1.1%) (NBS, 2020). Growth performance of agriculture is therefore largely driven by the performance of crop sub-sector on account of its dominance.

The major root and tuber crops grown in Nigeria are cassava (*Manihot esculenta*), yam (*Dioscorea spp*.), sweet potato (*Ipomoea batatas*), cocoyam (*Xanthosoma spp* and *Colocasia spp*), while others which are gaining prominence are carrot (*Daucus carota*), ginger (*Zingiber officinale*) and irish potato (*Solanum tuberosum*). They are grown in varied agro-ecologies and production systems contributing to more than 240 million tons annually, covering around 23 million hectares (International Institute of Tropical Agriculture [IITA], 2015).

There are many compelling reasons for encouraging production of root and tuber crops for sustainable food production in Africa. They are versatile staples to address nutrition and food security for millions of people, and produce more food per unit area of land which underlines their ability to spur agricultural growth. These crops are also capable of efficiently converting natural resources into more usable products, caloric energy in the growing season, which is the most productive of all major arable crops; almost double that of wheat and rice.

Root and tuber crops have continued to play a significant role in the agricultural production and growth in Nigeria. Nigeria is the largest producer of most of the root and tuber crops in the world with a yearly output of 59 million metric tons for cassava (about 20% of global production), 41.1 million metric tons for yam (about 70% of global production), 5.49 million metric tons for cocoyam (about 46% of global production) and 4.14 million metric tons for sweet potato (IITA, 2019). Food and Agriculture Organization (2018) asserted that the growth rates of root and tuber crops has shown some upward improvement in recent years.

Total production of roots and tuber crops in sub-Saharan African was estimated as 254 million tons per annum, of which cassava production had the largest share of 132 million tons/annum followed by yam, 56 million tons/annum and sweet potato 17 million tons/annum (FAOSTAT, 2013). In all, sub-Saharan African produces about 20% of the world's total production of root and tuber crops, for about 10% of the world's total human population (FAOSTAT, 2013). Roots and tuber crops are of utmost importance for the world food security as they are major sources of energy in developing countries characterized by fast population growth. Nigeria's position in the production of some of these root and tuber crops is quite outstanding especially with regards to cassava and yam.

Historically, the production of roots and tubers in Africa has been restricted to assuring food security. However, due to a lack of participatory policy making and institutional development, virtually all colonial governments neglected their production and trade in favour of cash crops such as tea, coffee, cotton, and cocoa or cereals (Nweke, 2004). This meant that, amongst other things, the private sector driven participatory plant breeding that characterized some of the cash crops bypassed roots and tubers, leading to an under performance of the sub-sector which has direct implications for agricultural growth and food security.

During the past four decades, food production has failed to keep pace with population growth in many African countries. Severe food insecurity continues, food import bills have been soaring and agricultural export earnings have been declining. To reverse these trends, African countries have been called to increase agricultural productivity. One group of commodities that holds much potential for reversing this trend is the roots and tubers (Joel, 2009).

Despite the importance of roots and tubers in Africa, African food policy over the last half a century has focused on achieving growth and self-sufficiency in cereals such as wheat, rice and maize, with growth rates in roots and tubers over this period largely driven by area expansion as opposed to yields [resulting from technological innovations such as improved varieties and production techniques] (Scott *et al*., 2000; Nweke, 2004).

Productivity growth rates in Sub-Saharan Africa have been disappointing except in the case of yam. Increases in yield are often difficult to achieve in the region because of nutrient-poor soils, lack of irrigation, and weak infrastructure (Spencer and Badiane, 1995). Also, the productivity of cassava in Africa is 37-64% below the global value. In 2013, Nigeria reached 14.1 tons/ha, similar to Brazil but 37% less than Indonesia (22.5 tons/ha) and Thailand (21.8 tons/ha) (FAOSTAT, 2015).

Furthermore, IITA (2015) posited that although root and tuber crops have shown tremendous growth over the past three decades relative to other crops, virtually all production increases have resulted from increasing the land area planted and not significant yield increases. The crops are plagued by diseases and pests and this has constrained yield improvement and produce quality. Consequently, this results to low productivity of roots and tuber crops which in turn retards agricultural growth and breeds food insecurity in Nigeria.

Ochoche, Abah and Biam (2022) posited that instability in the area, production and productivity of root and tuber crops could be detrimental for food security given that roots and tubers is a source of income for poor farmers and of food for the rural and

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urban poor. Therefore, reducing instability will ensure sectorial growth and enhance food security which is an essential part in eradicating hunger and poverty in the country. It becomes imperative therefore to study the growth and performance of root and tuber crops and agricultural growth in Nigeria over the years. This study therefore assessed the growth rates and doubling time of the area, production and productivity of root and tuber crops and agricultural growth in Nigeria and their implication on food security.

2. METHODOLOGY

2.1. Study Area

The study area is Nigeria. Nigeria is located on the Gulf of the Guinea in West Africa with a geographical area of 923, 768 square kilometers. It is one of the eight most populous countries in the world with a population of about 140 million (NPC, 2006). With a population growth rate of 2.6%, Nigeria has an estimated population of about 210.87 million in 2021 (www.statista.com). Nigeria lies wholly within the tropics along the Gulf of Guinea on the western coast of Africa. The topography ranges from mangrove swampland along the coast to tropical rain forest and savannah to the north. Nigeria is located between latitude 4°16 and 13°53 north and longitude 2°40 and 14°41 east (CIA Fact Book, 2009).

Because Nigeria has a highly diversified agro-ecological climate, agriculture is one of the most important sectors of the Nigeria economy. The climate varies with Equatorial in South, Tropical in Centre and in the North. In the North, the vegetation is grassland savannah and in the south, forest. Because of this vegetation, agriculture is the major employer of labour in the country. In terms of employment, at least 60% of Nigeria's projected population of 210.87 million, is estimated to be engaged or employed in agriculture (mainly small holders). Women make up to 60-80 percent of work or labour and produce two thirds of food crops.

2.2. Methods of Data Collection and Analysis

The study basically relied on the use of time series data spanning from 1981 to 2020. Data on the variables for the study were collected from the archives of Food and Agriculture Organization (FAO) and World Bank database. Specifically, data on area, production and productivity of root and tuber crops and food security were collected from FAO while data on agricultural growth were collected from World Bank. Data for this study were analyzed using both statistics and the growth model.

2.3. Model Specification

2.3.1 Growth model

The trend equation is given as:

$Y_t = Y_0(1+r)^t$………………..…………………………………………………………..… (1)

Where:

Y_t = R&T area, production or productivity, agricultural growth in year t

Y_0 = R&T area, production or productivity, agricultural growth in the base year.

r = Compound rate of growth of Y,

t = time trend variable

By taking the natural logarithm of both sides, the linear form of the equation was obtained making it amenable to OLS as;

$\ln Y_t = \ln Y_0 + t\ln(1+r)$ ...…………………………………………………………………(2)

Substituting in $\ln Y_0$ with α and $\ln(1+r)$ with β, equation (2) is rewritten as

$\ln Y_t = \alpha + \beta_t$……..………………………………………………………………… (3)

Adding the disturbance or error term to equation (3), we obtain

$\ln Y_t = \alpha + \beta_t + U_t$………..……………………………………………………………… (4)

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Equation (4) is the growth rate model developed for this study.

Growth model used to ascertain direction and growth rates of variables of interest were specifically stated for the variables of interest as follow:

$\ln Y_t = \alpha + \beta_a t + \mu_t$ …………………………………………………………………………. (5)

$\ln Y_t = \alpha + \beta_p t + \mu_t$ ………………………………………………………………………….. (6)

$\ln Y_t = \alpha + \beta_y t + \mu_t$ …………………………………………………………………………. (7)

$\ln Y_t = \alpha + \beta_{ag} t + \mu_t$ ………………………………………………………………………. (8)

Where:

α = intercept;

β = vector of the trend variable and μ is the econometric error term.

B_a, β_p, β_y, β_{ag} = coefficients of the trend variable for area, production, productivity of root and tuber crops and agricultural growth respectively.

The parameter of utmost interest in equations (5-8) is coefficient of β, the slope coefficient which measures the constant proportional/relative change in Y for a given absolute change in the value of the regressor t.

Firstly, multiplying b by 100, gives the instantaneous growth rate (IGR) at a point in time.

IGR= β X 100 ………………………………………………………………………… (9)

Where:

IGR = Instantaneous growth rate and

β = is the least-square estimate of the slope coefficient

Secondly, the compound growth rate (CGR) in percentage in each of the five cases can be recovered from the equations 5-8 in the following manner:

CGR = $(e^{\beta i} -1)*100$ ………………………………………………………………… . (10)

Where:

β_i = the coefficient of the trend variable in the respective cases

e= Euler's exponential constant (=2.71828)

Doubling time which is the number of years it will take to double the rate of growth of a time series was computed following Isah *et al.* (2015) as follows:

DT = 69/r ……………………………………………………………………………………….. (11)

Where: DT = Doubling time, r = compound rate of growth as in equation (10).

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In order to estimate the direction or pattern of growth so as to determine whether there is acceleration, deceleration or stagnation, quadratic equation in time trend variable was fitted as follows:

$LinY_t = \beta_o+\beta_1 t_i+ \beta_2 t_i^2 +Ut$ …………………………………………………………………….. (12)

All variables as previously defined, β_o, β_1 and β_2 are parameters to be estimated. In the specification of equation 12, the linear and quadratic time terms indicate the circular path in the dependent variable (Y_t). The quadratic time variable (t^2) allows for the possibility of determining whether there was acceleration, deceleration or stagnation in the study (Maikasuwa and Ala, 2013). In determining the direction or pattern of growth, the main concern is on β_2 (i.e. coefficient of t_i^2) which reveals the measure of the growth pattern following Isah *et al.* (2015) and Maikasuwa and Ala (2013).

Finally, in equations 12, if β_2 is positive and statistically significant there is acceleration in growth, if β is negative and statistically significant there is deceleration in growth, if β is not statistically significant there is stagnation in the growth process.

3. RESULTS AND DISCUSSION

3.1 Growth Rate, Direction and Doubling Time of Area, Production and Productivity of Root and Tuber Crops and Agricultural Growth in Nigeria

3.1.1 Growth rate, direction and doubling time of area of root and tuber crops

The result of the growth trend analysis is presented in Table 1. The exponential growth model was chosen from different functional forms as a good fit based on the low value of Akaike information criterion (AIC) and coefficient of determination (R^2). The coefficient of multiple determination (R^2) value of 0.964 implies that 96.4% of the variations in the trend of area was explained over time by the trend model. The result revealed that the coefficient for estimating the growth of area of root and tuber crops was positive (0.0831) and significant at 1%. The instantaneous growth rate (growth at a point) was 8.31% suggesting that there has been an 8.31% per annum increase in the area devoted to root and tuber crops cultivation for the period 1981-2020. The compound growth rate of area of root and tuber was 8.67%. This implies a relatively slow process of growth in area of root and tuber particularly during the period 1981-2020. This is in line with the findings of Kenyon *et al.* (2006) who opined that the area devoted to root and tuber crops has experienced positive growth rates over the years.

The doubling time computed for the compound growth rates in years for area of root and tuber was 7.96 years. This implies that given the present trend, the rate of increase in area devoted to root and tuber cultivation would be doubled in the next 7.96 years (2029).

The quadratic term (t^2) in equation (12) allows for the possibility of acceleration, deceleration or stagnation in the area growth processes. Results in Table 1 showed that the value of the coefficient of t^2 for area (-0.0007) was negative and significant implying a decelerated growth process in the area devoted to root and tuber cultivation.

3.1.2 Growth rate, direction and doubling time of production of root and tuber crops

The exponential growth model was chosen from different functional forms as a good fit based on the low value of Akaike information criterion (AIC) and coefficient of determination (R^2). The growth trend results for production of root and tuber crops as shown in Table 1 revealed that the coefficient for estimating the growth of production of root and tuber crops was positive (0.1117) and significant at 1%. The instantaneous growth rate (growth at a point) was 11.17% suggesting that there has been an 11.17% per annum increase in the production of root and tuber crops for the period 1981-2020. The compound growth rate of production of root and tuber was 11.83%. This implies a relatively moderate process of growth in the production of root and tuber crops particularly during the period 1981-2020. The coefficient of multiple determination (R^2) value of 0.958 implies that 95.8% of the variations in the trend of root and tuber crops production was explained over time by the trend model. This is in line with Ojiako *et al*. (2007) who reported an average annual growth rate between 4-8% of major root and tuber crops in Nigeria.

The doubling time computed for the compound growth rates in years for the production of root and tuber was 5.84 years. This implies that given the present trend, the rate of increase in the production of root and tuber would be doubled in the next 5.84 years (2027).

The direction or pattern of the growth processes from the quadratic term (t^2) as shown in Table 1 revealed that the value of the coefficient of t^2 for production (-0.0015) was negative and significant implying a decelerated growth processes in the production of root and tuber crops. This implies that the growth of root and tuber crops production has not been at a geometric rate over the

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years. Verter and Bečvářová (2015) reported that the growth rate of root and tubers production in SSA is far from consistent, especially in Ghana and Nigeria.

3.1.3 Growth rate, direction and doubling time of root and tuber crops productivity

The exponential growth model was chosen from different functional forms as a good fit based on the low value of Akaike information criterion (AIC) and coefficient of determination (R^2). The results of the growth trend for productivity of root and tuber crops shown in Table 1 further revealed that the coefficient for estimating the growth of productivity of root and tuber crops was positive (0.0289) and significant at 1%. The instantaneous growth rate (growth at a point) was 2.89% suggesting that there has been an 2.89% per annum increase in the productivity of root and tuber crops for the period 1981-2020. The compound growth rate of productivity of root and tuber was 2.92%. This implies a very slow process of growth in root and tubers productivity particularly during the period 1981-2020. The R^2 value of 0.579 implies that 57.9% of the variations in the trend of productivity of root and tuber crops was explained over time by the trend model.

The doubling time computed for the compound growth rates in years for the productivity of root and tuber was 23.63 years. This implies that given the present trend, the rate of increase in the productivity of root and tuber would be doubled in the next 23.63 years (2045). Therefore, productivity growth trend needs to be improved in order to reduce the doubling time.

The direction or pattern of the growth processes from the quadratic term (t^2) as shown in Table 1 revealed that the value of the coefficient of t^2 for productivity (-0.0009) was negative and significant implying a decelerated growth processes in the productivity of root and tuber crops. This implies that the productivity of root and tuber crops in Nigeria has been rather quite low. This is in line with the findings of Kenyon *et al.* (2006) who posited that the yields of root and tuber appears to have remained static over the years. The further opined that productivity growth rates are often difficult to achieve in Nigeria because of nutrient-poor soils, lack of irrigation, weak infrastructure, inconsistency in Government policies amongst others.

3.1.4 Growth rate, direction and doubling time of agricultural growth

The result of the growth trend analysis of agricultural growth is presented in Table 1. The exponential growth model was chosen from different functional forms as a good fit based on the low value of Akaike information criterion (AIC) and coefficient of determination (R^2). The results of the growth trend of agricultural growth shown in Table 1 also revealed that the coefficient for estimating the growth of agricultural growth was positive (0.028) and significant at 1%. The instantaneous growth rate (growth at a point) was 2.80% suggesting that there has been a 2.80% per annum increase in agricultural growth for the period 1981-2020. The compound growth rate of agricultural growth was 2.84%. This implies a relatively slow process of growth in agriculture particularly during the period 1981-2020. The coefficient of determination (R^2) value of 63.2 implies that 63.2% of the variations in the trend of agricultural growth was explained over time by the trend model. This finding is consistent with various World Bank and CBN reports that stipulated that agricultural growth rate in Nigeria has been between 2.0-3.0% over the years.

The doubling time computed for the compound growth rates in years for agricultural growth was 24.29 years. This implies that given the present trend, the rate of increase in agricultural growth would be doubled in the next 24.29 years (2025).

The direction or pattern of the growth processes from the quadratic term (t^2) as shown in Table 1 revealed that the value of the coefficient of t^2 for agricultural growth (-0.027) negative and significant implying a decelerated growth in agriculture in Nigeria during the period.

Table 1. Growth Trend Model

Variables	Model	Determinant	Coefficient	t-stat	Prob.	R^2	F-stat	AIC
Agricultural growth	Linear	Trend	0.1337	2.203	0.0337	0.113	4.853	5.87
		Constant	14.420	333.752	0.0000		(0.033)	
	Exponential	Trend	0.028	6.694	0.0000	0.632	44.814	-0.86
		Constant	2.509	26.396	0.0000		(0.000)	
	Quadratic	Trend	1.217	7.859	0.0000	0.633	31.885	5.03
		Trend^2	-0.027	-7.24	0.0000		(0.000)	
		Constant	13.399	10.362	0.0000			
Area	Linear	Trend	0.0538	20.219	0.0000	0.938	524.795	30.85
		Constant	14.408	235.210	0.0000		(0.000)	

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	Exponential	Trend	0.0831	10.721	0.0000	0.964	644.581	-0.73
		Constant	14.543	285.092	0.0000		(0.000)	
	Quadratic	Trend	0.057	25.387	0.0000	0.958	421.579	30.36
		Trend^2	-0.0007	-3.464	0.0014		(0.000)	
		Constant	14.379	220.002	0.0000			
Production	Linear	Trend	0.088	16.218	0.0000	0.899	298.320	34.16
		Constant	16.541	259.279	0.0000		(0.000)	
	Exponential	Trend	0.1117	16.812	0.0000	0.982	382.632	-0.06
		Constant	16.804	235.927	0.0000		(0.000)	
	Quadratic	Trend	0.0528	15.0472	0.0000	0.958	421.277	34.18
		Trend^2	-0.0015	-8.2001	0.0000		(0.000)	
		Constant	16.4317	262.629	0.0000			
Productivity	Linear	Trend	-0.004	-2.215	0.0329	0.114	4.903	3.31
		Constant	4.262	83.956	0.0000		(0.000)	
	Exponential	Trend	0.0289	2.271	0.0289	0.579	25.157	-1.03
		Constant	2.262	51.529	0.0000		(0.000)	
	Quadratic	Trend	0.248	5.369	0.0000	0.598	27.518	2.62
		Trend^2	-0.007	-6.392	0.0000		(0.000)	
		Constant	11.2619	257.469	0.0000			

Figures in parenthesis are p values of the F-statistics

Source: Data Analysis, 2021.

Table 2. Growth Rates, Direction and Doubling Time of the Variables

Variables	IGR (%)	CGR (%)	Doubling time	Year doubling would be achieved	Direction of growth
Area	8.31	8.67	7.96	2029	Deceleration
Production	11.17	11.82	5.84	2027	Deceleration
Productivity	2.89	2.92	23.63	2045	Deceleration
Agricultural growth	2.80	2.84	24.29	2045	Deceleration

Note: IGR = Instantaneous growth rate; CGR = Compound growth rate

Source: Data Analysis, 2021.

3.2 Summary statistics of the variables

The summary statistics of the variables used in the study is presented in Table 3. The result showed that the variables agricultural growth and area were positively skewed to the right tail implying the presence of more values that are higher than the sample mean while the variables production and productivity were negatively skewed to the left tail implying the presence of more values that are lower than the sample mean.

The result further showed that the variables agricultural area, production and productivity were platykurtic (negative kurtosis) with a kurtosis value less than 3 implying that the distribution had a flatten curve relative to the normal. This shows that there were more values that are lower than the sample mean. The variable agricultural growth was leptokurtic (positive kurtosis) with a kurtosis value greater than 3 implying that the distribution had a peak curve relative to the normal.

More so, the result of the Jarque-Bera probability test of normality showed that the variables (area, production and productivity of root and tuber crops and agricultural growth) were not statistically significant at 5% significant level having probability values greater than 0.05 (5%) which indicated the normal distribution of the variables.

Table 3. Summary Statistics of the Variables

	Agric. Growth	Area	Production	Productivity
Mean	22.86948	7747210	66175248	8.910043
Median	22.07050	7634000	65355500	8.853800
Maximum	36.96508	16500407	117649974	10.88330

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Minimum	12.24041	2004000	15310000	6.421800
Std. Dev.	4.647603	4618691	33208711	1.296687
Skewness	0.442825	0.483462	-0.068837	-0.107991
Kurtosis	4.624443	2.089833	1.914837	1.719849
Jarque-Bera	5.705318	2.938908	1.994220	2.809057
Probability	0.057691	0.230051	0.368944	0.245483
Sum	914.7793	310000000	2650000000	356.4017
Sum Sq. Dev.	842.4082	8.32E+14	4.30E+16	65.57452
Observations	40	40	40	40

Source: Data Analysis, 2021.

4. CONCLUSION, POLICY IMPLICATIONS AND RECOMMENDATIONS

The study revealed that it will take at least twenty (20) years to double the rate of increase in agricultural growth and root and tuber crops productivity in Nigeria. This is quite a long time and points to a rather slow pace of growth in the sector which is unfavorable in the quest to achieve food security. This calls for greater participation and synergy among all actors in the agricultural sectors to boost the tempo of root and tuber crops production in order to achieve the long-term goal of food security in Nigeria.

The study concludes that the area, production and productivity of root and tuber and agricultural growth rates in Nigeria has not been at an exponential rate as evidenced by the decelerated growth pattern of the variables over time in Nigeria. This trend and decelerated pattern of growth is not healthy in addressing food security in Nigeria as the nation continues to battle with the grappling effects of food insecurity. Improving root and tuber crops productivity and agricultural growth and is vital towards the attainment of food security in Nigeria.

The study therefore recommended that Government, NGOs and other actors in the agricultural sector should develop new policies, institutions and financing structures to increase root and tuber crops production and productivity and consequently drive sector growth as the sub-sector is crucial in reducing food insecurity in Nigeria. Furthermore, capacity building and development for farmers should be periodically carried out in order to enhance their efficiency so as to increase root and tuber crops productivity.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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